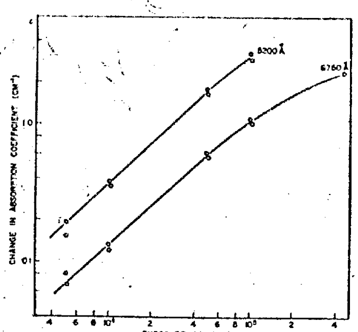

Fig. 1. Change in absorption coefficient as a function of Co^{60} exposure at 21°C.

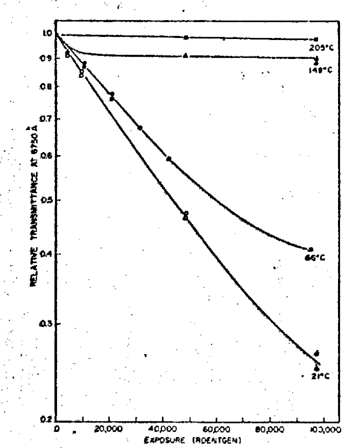

Fig. 2. Relative transmittance as a function of Co^{60} exposure.

The surfaces through which optical measurements were made were lapped successively with 600- and 1200-mesh abrasive and then polished with Linde A abrasive until approximately 80% transmittance relative to air at 6750 Å was obtained. The finished specimens averaged 1.3 cm in thickness.

All spectral measurements were made with a Beckman DK-2 Ratio Recording Spectrophotometer. The exposures were carried out in a Co^{60} irradiator (U.S. Nuclear Model SDF-11-C) nominally rated at 900 ci. The dose rate was determined by air-equivalent ion chamber measurements to be 1.28×10^5 R/h. A variable temperature heating cavity was fabricated to facilitate exposures at elevated temperatures. In these latter studies sufficient time was allowed for the specimens to reach the desired temperature before exposure. To reduce errors due to fading, transmittance measurements were made immediately after completion of exposures.

From exposures made at 21°C, it was found that the radiation-induced transmittance losses resulted from two broad absorption bands centered around 3200 Å and 7000 Å. No radiation-induced absorption bands were found in the region from 15,000 Å to 21,000 Å for exposures up to 10^5R. The change in the optical absorption coefficients at 6750 Å and 5200 Å are shown in Fig. 1 for samples exposed at 21°C. It is seen that at both wavelengths the absorption coefficient shows an almost linear increase with dose up to 10^3R after which a decided nonlinearity appears. Similar results have been reported from studies made on other glasses.[1,2]

The effect of maintaining samples at elevated temperatures during exposure is illustrated in Fig. 2 where relative transmittance (ratio of post-irradiation transmittance to pre-irradiation transmittance) at 6750 Å is plotted against exposure at four temperatures. It is seen that appreciable reduction in transmittance losses is offered by maintaining samples at a temperature as low as 66°C. In a 205°C environment, the transmittance remained within 3% of its pre-irradiation value after exposure to 10^5R.

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Coherent Detection of Light Scattered from a Diffusely Reflecting Surface

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In a previous demonstration of optical heterodyne detection,[1] specular reflectors were used to generate the signal and local oscillator beams from a single laser.[2] In this letter, we report the coherent optical detection of a signal beam scattered from a diffusely reflecting surface. When different areas of the diffuse reflector were illuminated, variations in signal were observed which can be related to the "granularity" phenomenon directly observable with a visible laser.[3] The average value of the signal obtained was in agreement with that to be expected from a Lambertian diffuse reflector. The observed signal fluctuations were consistent with the Rayleigh distribution predicted by a stochastic theory of diffuse reflectors.

When using the optical heterodyne or homodyne technique, it is essential that spatial and temporal coherence be maintained between local oscillator and signal beams. In general, light reflected from a diffuse surface is not spatially coherent, but can be viewed as having originated from an extended distribution of random sources, each radiating at the excitation frequency. From the theorem of van Cittert and Zernicke,[4] it can be shown that the field radiated from an extended source will be spatially coherent over any receiver aperture which cannot resolve the dimensions of the source. This condition can always be approximately fulfilled, (assuming receiver and transmitter have the same aperture), by focusing the transmitted beam to a Fraunhofer diffraction spot on the diffuse surface.

Figure 1 shows the experimental arrangement used for measuring heterodyne signal and noise. Optical feedback into the laser was prevented by the use of a quarter-wave plate (λ/4) and a polarizer (P). The laser (6328 Å He–Ne) was operated in the folded-concentric configuration. The oscillation was maintained in a single spatial and temporal mode, monitored visually by means of a plane Fabry–Perot interferometer, F–P. The laser output (6 mm in diam, D) was collimated by lens L_1 and focused by lens L_2 (200-cm focal length, F) to a Fraunhofer spot on diffuse, reflector, r. The reflector consisted of ordinary white bond paper glued to the face of a glass flat which, in turn, was glued to a piezoelectric ceramic disk, X. Part of the flat was gold-coated for purposes of comparison with the case of specular reflection. Phase modulation of the return beam was accomplished by applying a sinusoidal voltage to the piezoelectric disk. The depth of modulation was 0.3 rad at a frequency of 1000 cps.

The phase modulation was demodulated by maintaining a 90°-phase difference between the signal and local oscillator beams.[2] This condition was achieved by adjusting the length of the local oscillator arm to maximize the homodyne signal. The 1000 cps signal in the photomultiplier, Φ, (RCA 7326, quantum efficiency: $\eta = 0.05$) output current was measured with an rms-reading audio spectrum analyzer.

Rigden and Gordon[3] have described the nonuniform spatial radiation patterns which occur when coherent light is reflected from a diffuse surface. In order to determine the effect of these spatial fluctuations on the signal beam power at the detector, the diffuse reflector was moved transversely across the beam by means of a micrometer screw, M.

The experiment consisted of the following: the homodyne signal current was measured with a specular reflector located at the focused spot, after careful alignment of local oscillator and signal beams. The specular reflector was then replaced by the diffuse reflector, oriented approximately normal to the beam, and a series of signal and noise measurements were then made, corresponding to different positions of the diffuse reflector, 0.05 mm apart. In each measurement the local oscillator arm was adjusted with an interferometer control to maintain the phase angle between the signal and local oscillator beams in quadrature. During each measurement, while the illuminated area was held fixed, the observed noise was constant and equal to the shot noise on the photocurrent generated by the local oscillator, as expected for optical heterodyne detection.[1] However, the observed heterodyne signal varied with position of the illuminated area on the diffuse reflector as shown in Fig. 2.

If the (depolarizing) diffuse reflector is a Lambert reflector, one would expect the ratio of specular to diffuse signal, close to normal incidence, to be $(2\pi\rho_s/\Omega\rho_d)^{1/2}$ where ρ_s and ρ_d are the specular and diffuse reflectivities and Ω is the solid angle subtended by the receiver aperture at the diffuse surface.

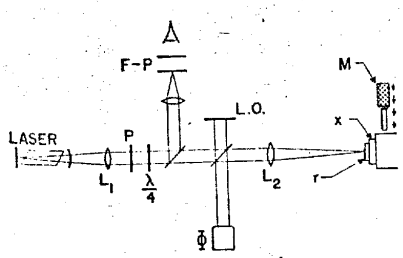

Fig. 1. Experimental arrangement.

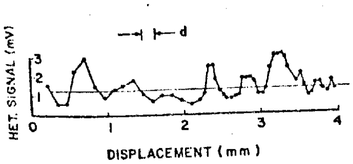

Fig. 2. Heterodyne signal vs transverse displacement of diffuse reflector.

The variations shown in Fig. 2 may be described theoretically by constructing a statistical model of the diffuse reflector which describes a Lambert radiator. The model which was used assumed that the reflected field was generated by a random current distribution, **i**, over the volume of the reflector. It was assumed that the phase components of each vector component of **curl i** were independent Gaussian stochastic processes with an average value of zero and with the same two-point correlation functions. It then follows that the experimentally measured heterodyne signal, S, is a random variable which has a Rayleigh distribution. For this distribution the various moments of S satisfy the relations

$$\frac{\langle S^{2n}\rangle}{\langle S^{n}\rangle^{2}} = \frac{\Gamma(1+n)}{\Gamma^{2}[1+(n/2)]}.$$

This ratio does not depend on the parameters of the distribution, and hence is insensitive to the details of the statistical model.

As shown in Table I, the average heterodyne signal from the diffuse reflector is within a factor of two of the result extrapolated from the case of specular reflection. The agreement between the experimental and theoretical values of the moments of the distribution of heterodyne signals strongly supports the validity of the model of diffuse reflectivity in the present case.

Table I. Diffuse Reflector Results

	$\langle S\rangle$	$\langle S^2\rangle/\langle S\rangle^2$	$\langle S^4\rangle/\langle S^2\rangle^2$
Exp.	1.4 mv	1.24	1.96
Theoret.	2.5 mv[a]	1.27	2.00

[a] Based on measured $\langle S\rangle_{specular} = 2500$ mv, $\rho_s = 0.95$, $\rho_d = 0.7$.

Correlation was observed in the measured heterodyne signal for displacements less than the diameter of the focused spot, d, ($d \approx F\lambda/D = 0.2$ mm). If the diffuse surface were in motion with respect to the optical beam, fluctuations similar to those described above would occur and produce random modulation of the signal beam. The detected signal would then have a noise bandwidth, which is approximately V/d, where V is the velocity at which the illuminated spot traverses the surface.

In summary, the present work has shown the applicability of the optical heterodyne technique to diffuse, as well as specular, surfaces but indicates that an effective loss of temporal coherence is to be expected for moving reflectors.

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